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AUTHOR	Settel, Joanne; Hooe, Tom N.
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ABSTRACT

This document discusses an introductory biology course that uses constructivist principles. Students observed phenomena and were engaged in activities before studying the content to ensure that the laboratory sections of the course were more than "look and see" or confirmatory experiments. The student handout is provided. (YDS)

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CONSTRUCTING THE STREAM COMMUNITY: THE ECOLOGY OF FLOWING WATERS

Joanne Settel and Tom N. Hooe
Department of Natural and Physical Sciences
Baltimore City Community College
Baltimore, MD 21215

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"An individual can and cannot step into the same river twice"
—(Heraclitus)

In restructuring our introductory biology course, we wanted to set a stage for our students that was not based upon dogma, sterile content, or rigid process, but rather on the changing nature of systems so well exemplified by the "stream." As implied by the quotation by Heraclitus above, nothing stays the same; the passage of time brings change. The stream community, a prime setting for observing the effects of time on a system, became a symbol of change for our course as well as its central theme. During the course we changed both processes and pedagogy to meet the needs of students at various points in time. We were not fixed to a set schedule and felt the need to be free to adapt to any learning situation.

Context and Goals

We first taught the MCTP course "Principles of Biology" in the fall semester of 1995. Our course was an "Honors Section" with 24 students who were screened to be a part of the honors program; three of them were preparing to become teachers.

Prior to our MCTP section, this foundation course had been taught in a traditional lecture/laboratory format. Most of the labs in the traditional section were hands-on, but not constructivist-based. Students were given background information and explicit instructions on how to perform procedures; this was followed by discussions of results. Students were asked to do very little connecting and integrating of knowledge they had gained. Content was more important than process.

Our major goal for the course was to restructure the way in which students (and instructors) assemble, learn and evaluate biological principles. Based on our study of constructivist principles, we drastically changed the course design. We agreed that instead of just learning biological principles in an isolated format, students might better master the concepts if they could tag biological principles onto real life experiences. We also decided to vary from traditional lecture/lab courses by ensuring that students observed phenomena and engaged in activities *before* formally studying biological principles. By reversing the order of exposure for students, we hoped that the laboratory would become more than just a "look—see—I told you so" experience. (In fact it did; it actually became a place for discovery.) Here is an overview of the changes we made:

- The course followed a central theme or strand, "The Stream Community."
- The course was team-taught, with both professors present in the classroom most of the time.
- The biological principles examined in the course were integrated with underlying mathematics and physics concepts.
- The course was inquiry-based: Introduction of concepts often began with observing

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phenomena, experimenting, and collecting data, rather than through lectures.

- Technology was integrated into course activities, with students using computer spreadsheets, graphing software, and computer statistical evaluation.
- Preconceptions and misconceptions of students were identified and sometimes became the starting point for classroom activities.
- Questioning and question development was central to student-teacher interactions. Great care was taken to develop questioning techniques.
- Cooperative learning was supported from the beginning of the course and was recognized by both students and instructors as a powerful learning tool.
- Literature and writing reinforced the learning of biological concepts. Relevant research articles were assigned for reading, and both professors and students kept journals.
- Words like *predicting, hypothesizing, analyzing,* and *classifying* became a part of our daily routine. Students sometimes wondered if the instructors were ever going to answer one of their questions directly.
- The instructors had to "buy in" to the idea that "less is more" from a learning/instructional standpoint. Nevertheless, many of the principles that would be found in an introductory biology text were included.

In adopting the less is more principle, we devised three main themes for the course: Energy in Biological Systems, Evolution, and the Stream Community. Concepts related to the first theme, energy in biological systems, were constructed and reinforced through a variety of activities on surface area-to-volume ratios, photosynthesis, metabolism, and organism adaptations to thermal loss. For our evolution theme, we engaged students in plant genetics and population dynamics activities, and added a zoo field trip, after which students were able to construct models for vertebrate limb evolution. This case report focuses on our third and central theme, that of "The Stream Community."

Exploring the Stream: New Depths of Understanding

In keeping with our goal to help students tag principles of biology onto real life experiences, we began the course with a field trip to a stream in southern Pennsylvania. There, our group of inner-city students got what was, for most of them, their first chance to observe numerous parameters of a stream ecosystem. They collected data on both living and non-living stream features, which became the focus for later units on the following topics:

- water and its properties;
- pH and the effects of acid rain and mine waste on ecosystems;
- classification and the use of simple dichotomous keys;
- photosynthesis and primary production in the stream; and
- construction of food webs and pyramids of biomass.

The student handout to follow outlines our expectations for this activity.

Student Handout

CONSTRUCTING THE STREAM COMMUNITY: THE ECOLOGY OF FLOWING WATERS

Introduction

The ever-changing nature of streams makes them interesting communities to study. Because the water is flowing, the condition of a stream one minute is not exactly the same as in another minute.

Streams are divided into two major sections—riffles and pools—which usually alternate down a stream. The nature of each is determined by flow rate. Water flow also plays a major role in the kinds of adaptations made by the aquatic life found in the stream.

The stream is also a unique community due to the nature of its energy flow. Where does all the energy come from to support such an abundance of life? In most ecosystems the driving energy comes from within the system, from photosynthesis by plants. By contrast, the stream community gains much of its energy from external plant material that falls into the stream.

A stream's measurable physical parameters—such as pH, flow rate, and dissolved oxygen—are of great importance in determining its health, that is, its ability to support plant and animal life. For most organisms in the stream to thrive, these parameters must stay within very narrow ranges. In addition, the adverse effects of pollution often work against the health of a stream.

In this unit you will measure physical factors and observe stream organisms prior to your formal investigation of this community. You will be asked to arrange the organisms in the community by assembling a food web and a pyramid of energy. You will be further asked to predict the effect of acid rain, one changing parameter, on the community. This activity will be accomplished early in the semester and references will be made to it throughout the remainder of the course. Math and chemistry concepts, along with classification skills, will be integrated into this unit.

In today's study we will measure and observe a stream, looking in particular at the organisms there. We will also try to determine if the stream is healthy or polluted. So let's get started observing our stream. Remember to wear some real old shoes or sneakers because to do our work we will have to wade in some very rocky, shallow water.

The Riffles

The riffles of a stream are waters that move very rapidly (50 cm/second or faster), have a high oxygen concentration (at least 10mg/L) and a good pH value (above 7), and contain organisms like caddisflies, mayflies and stone flies. Trout and other stream fishes are also found in riffles.

With your instructors' help you should:

1. Measure the speed of the stream using the meter stick, watch and cork. Record your data.
2. Using a kick seine or by picking up rocks, collect as many aquatic insects as possible and identify them using the attached keys. Record your data.
3. Using the pH kit, measure the pH of your riffles. Record your data.
4. Using the thermometer, measure the temperature of your riffles. Record your data.
5. Using the dissolved oxygen kit, measure the dissolved oxygen level of the riffles. Record your data.

The Pool

The pool is much quieter than the riffles. Water in pools moves more slowly, is cloudier, has lower oxygen levels, and contains a much different group of organisms. Some of the organisms you will find in pools will be trout, bass, crayfish, leeches and plankton.

With your instructors' help you should:

1. Measure the speed of the stream using the meter stick, watch and cork. Record your data.
2. Help your leader use the drag seine to collect and identify as many organisms as possible. Record your data.
3. Use the pH kit to measure the pH of your pool. Record your data.
4. Use the thermometer to measure the temperature of your pool. Record your data.
5. Use the dissolved oxygen kit to measure the dissolved oxygen level of the riffles. Record your data.

We believed that the stream experience would be an interesting one for our students, but both of us were surprised by the amount of excitement and energy generated by this field trip. Even before we got to the site, the students were showing signs of both expectation and trepidation. Many of the students had not ventured far from Baltimore City previously and were at first hesitant to wade into the stream. After some bold students proceeded, all eventually got caught up in the excitement and were soon collecting data and organisms. The site itself was a quiet, wooded area reached through winding dirt roads, and students remarked later of the beauty of the countryside.

Comments excerpted from student and faculty journals illustrate how the stream environment was initially a little intimidating for an urban student, and how it also served to facilitate the "bonding" of classmates.

The thing that I am beginning to enjoy about our class is that we are learning while at the same time being occupied with fun and interesting activities. . . . We went to a stream near Professor Hooe's house in Pennsylvania today. I never could have thought I would have enjoyed myself so much. We split into groups and collected data on velocity, temperature, oxygen and pH and we sampled specimens from the riffles and pools. I think that our class bonded on this trip. . . . Although at times during the course I have felt discouraged because what's expected of us was a little ambiguous, I am very happy that I am in the program.

(David, 9/21/95)

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Well, we are back from the stream field activity and we had no casualties. We assembled at 8:00 a.m. and were back by 12:20 p.m. Quite a task since we drove all the way to Pennsylvania, did the stream in about an hour and a half and were back for other classes and the honors reception in the afternoon. The field experience went well and they made a great number of observations of biotic and physical components of the stream. The students were hesitant at first to immerse themselves into the stream but after a few minutes they were busy exploring the community.

(Professor Hooe, 9/21/95)

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Most of the students were quick to wade right into the stream and several exclaimed with delight as they experienced a stream for the first time. Several students were very tentative and held back until fellow students

chided them to join in. As the students began to feel more comfortable in the stream they began to venture further, collecting organisms from the different riffles and pools and taking pride in the number and variety of organisms found.

When we left the stream for the drive back to school, the students were still talking about the experience. They were actively generating ideas about how to determine if the stream was healthy. We were delighted by the experience and plan to use examples from the stream throughout the rest of the course.

(Professor Settel, 9/21/95)

Reflection on the Course as a Whole

We have spent many hours assessing the course and specific units. Below we share some of our feelings both of success and of possible failure.

We tried a new class format—a three-hour period, twice a week. At the onset we were afraid that the period would be too long, but we have found it to be just the opposite. It allowed us to vary the activities and to complete some activities that demanded the time. Students surprised us by spending more than the three-hour period engaged in class activities. Having the time, then planning and using it wisely, was essential.

We realized early on that we were not going to be able to cover all of the content that we had originally planned. Modifying our course outline, mid-stream, allowed us to select what we could reasonably do and still give the students experiences that we felt would be valuable in their construction of the concepts. We came to the realization that simply "covering" more material does not improve student learning. Instead, we adopted the "less is more" concept, which is hard for many professors to accept. But we believe that when assessments show that students really aren't learning effectively when you just "cover" the information, then you must search for new ways to facilitate student understanding.

One part of the teaching-learning process that still poses the greatest problem for us is the students' ability to apply constructed concepts to new problems or situations. For example, in our units on "Percent Composition of Living Cells" and "Surface-Area-to-Volume Ratios and Energetics," students were able to manipulate the math to solve the biological problems. But when we asked them to apply these skills and knowledge to a new situation, only about one-third of the class could reasonably do so. We plan in the next semester to do some initial assessment of developmental level, math proficiency and biological conception of students. We especially want to monitor concept accuracy, concept development and misconception of students through more extensive writing exercises in the course.

We came to the realization that simply "covering" more material does not improve student learning. Instead, we adopted the "less is more" concept, which is hard for many professors to accept.

An area of student concern that surfaced early on was their frustration with the fact that we did not answer all of their questions, and when we did, it was usually with another question. They eventually caught on to this inquiry-based approach, and they saw that we were trying to lead them to an answer instead of giving them the answer. They also began to use one another as resources, which really supported collaborative learning in the course.

We plan to change several other aspects of the course for the second offering, based upon observations that we made from the first course:

- We are changing how we use the journal as a device to give us student feedback about the course. We will probably be a little more structured in what we ask students to document in their journals.
- We are adding more structure and organization to the course to allow us to better manage it. This does not mean that we

are going away from the constructivist approach.

- We are going to devise new techniques to engage students with their preconceptions, misconceptions, and final conception of the topics covered. For example, we plan to have the students write their preconceptions and revisit them periodically, so that they confront the old concepts with the new.
- Team instructors are going to meet prior to every class to review strategy and pedagogy.
- We are going to respond to student requests for some closure at the end of units and some sort of a "big picture" review.
- We are changing the grading policy to include quizzes spaced at shorter intervals in the course.

Some final thoughts: We are committed to making student learning and assessment the driving forces for what we do as professors. Indeed, we will not spew information at students; we will continue to search for new and different ways to facilitate student learning. This will mean continuing to change pedagogy mid-stream to find alternative ways to assist students in their learning.

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Appendix

COURSE OBJECTIVES AND ASSESSMENT METHODS

Objectives

The student will be able to:

- construct concepts and biological ideas using knowledge gained from experimentation, observations, readings and classroom discussions;
- define selected biological nomenclature at the comprehension level of understanding in each of the topic areas of the course;
- construct and perform experiments in biology using standard laboratory apparatus and employing skills of hypothesizing, data collection, evaluation and drawing conclusions;
- construct an ecological community and its interactions using data from the stream study and information presented throughout the course; and
- maintain and organize data in a laboratory notebook, evaluate data by computer, and keep a course journal.

Assessment Methods

- *Laboratory Notebook and Journal* (20%). This book and journal will be reviewed every two weeks and at the end of the course for form, completeness, and accuracy.
- *Three Major Exams* (20% each). These exams will evaluate the student in the areas of knowledge (recall of facts), terminology comprehension (putting definitions in the students' own words), analysis and synthesis (analyzing data and putting together elements of a biological concept), and application of knowledge to new situations.
- *Project and Presentation* (20%). This aspect of evaluation will attempt to involve the student with library research on a topic of ethical or technological significance to biology and will measure the ability of the student to research, analyze and critically evaluate a topic.
- *Quizzes* were added to the course about half-way through at the request of students who felt that they needed to assess their progress at shorter intervals of time.

ADDITIONAL INFORMATION FOR INSTRUCTORS

Student Preconceptions

- A stream community might not have many living things in it (since they are not easily seen).
- All the energy that drives the stream community comes from within the stream.
- Stream life might be the same along its length.

Student Prerequisite Knowledge

- The student will have an understanding of water chemistry.
- The student will have an understanding of pH.
- The student will be able to measure using the metric system.

Student Learning Outcomes

The student will be able to:

- measure flow rate, pH, dissolved oxygen and temperature of two selected regions of a stream;
- observe and classify stream organisms using appropriate biological keys;
- predict the effect of flow rate on living and physical factors of the stream;
- construct a non-quantitative pyramid of energy and food web for the stream community; and
- predict and conduct research on the effects of acid rain on the stream community.

Related Activities

- Both before and after the field trip, we held laboratory activities in which we guided students through the process of identification of stream organisms using taxonomic keys. At the stream, we did not indicate any detail of any parameter of organism found, but instead asked questions that led the students to further research and investigation.
- After the stream study, students were asked to make a list based on class discussion of observable features of the stream, and to predict the effects of flow rate on living and non-living aspects of the stream.
- Students were asked to predict the effect of acid rain as one changing parameter on the community. This activity was accomplished early in the semester, and references were made to it throughout the course.

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